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MISCELLANEOUS REPORT NO. 15

CHEMICAL CONTROL OF BRUSH AND TREE GROWTH FOR THE LAKE STATES

By Paul O. Rudolf, Forester

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
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January 31, 1951

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By Paul C. Rudolf, Forester
Lake States Forest Experiment Station 1/

Frequently it is necessary to remove brush or trees which hinder the growth of more desirable trees, come in on fire lines, or block road, telephone, or power line right-of-ways. With hand methods, such work is expensive and usually must be repeated frequently; hence, cheaper practices have long been sought. 2/ Especially promising results have been achieved in the past five years with chemicals. During this time chemical control of woody plants has increased from a few hundred acres to several hundred thousand acres per year.

New chemicals have been developed so rapidly recently and have been applied in so many different ways to a great many woody plant species that it is difficult for workers to stay abreast of developments. It has become desirable, therefore, to summarize present knowledge of chemical control of woody plants, even though it will remain up-to-date but momentarily. Accordingly, this report attempts to bring together a brief summary of findings applicable to Lake States conditions and species.

Kinds of Chemical Herbicides 3/

Ideally, a chemical herbicide should be not only effective in killing weed species, but also reasonable in cost, easy to handle and apply, and safe to use. Many of the older herbicides were deficient in one or more of the latter requirements. (34)

Three general types of chemical herbicides have been used: (1) Those that kill by direct contact, (2) those that poison the soil and kill by being taken into the roots, and (3) those that kill by being translocated from the leaves or stems into the roots. Some chemicals kill by a combination of two or more of these processes. For most forestry purposes the contact-killers

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1/ Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota, University Farm, St. Paul 1, Minnesota.

2/ Also sought in a related field have been cheaper ways of removing bark from trees to be cut for pulpwood or other products.

3/ Herbicide is used here in its dictionary sense -- weed killer. Some writers use the term silvicide to designate materials for killing woody plants.

are not desirable because they kill only the tops. For some purposes the soil poisons also are undesirable. It is preferable to obtain a kill of the roots so as to prevent or severely retard sprouting. Generally speaking, the translocated herbicides hold the most promise for forestry use.

Some chemical herbicides are selective, although many are not. Both types can be useful in forestry. The selective kinds are needed for such operations as releasing young conifers overtopped by broadleaf brush or trees. The nonselective kinds are preferred on right-of-way brush control and similar situations where a general kill is sought.

Older Herbicides

From the late 1920's to date, sodium arsenite has been tested and found effective in killing a large number of woody plants when applied to cut stumps or in frills cut through the bark of the stems. Such diverse plants as hawthorn, aspen, eastern hophornbeam, and ponderosa pine (8, 19) have been controlled. The Cornell Tree Killing Tool was developed to enable one man to incise a tree and introduce the poison solution in one operation (8). More recently dilute sodium arsenite solutions have been painted on the bare wood exposed after girdling the stem, not only to kill the tree but also to promote easy bark removal. The main drawback to its more extensive use has been that sodium arsenite is highly poisonous to humans, livestock, and wildlife.

Such chemicals as other arsenicals, sodium chlorate, ammonium thiocyanate, and 27° Diesel oil also proved reasonably effective in controlling woody plants (22). All these materials, however, were either expensive or hazardous to use. Creosote, copper sulfate, zinc chloride, ammonium sulfamide, ammonium nitrate, and sodium nitrate have been found rather ineffective in killing woody plants (6).

Newer Herbicides

Within the last few years three new chemicals which are nonpoisonous to humans and animals have shown much promise as herbicides (11). They are: ammonium sulfamate, 2,4-D, and 2,4,5-T. All three kill by being translocated from leaves or stems down into the roots. They have been used in water solutions, oil solutions, and emulsions. Several studies are under way to determine the effectiveness of adding various materials (ethylene dibromide, dinitro compounds, pentachlorophenol, etc.) to aid penetration and translocation (4).

Ammonium sulfamate is a relatively simple salt marketed as "Ammate." It is essentially nonselective. It kills leaves and stems very rapidly and when properly applied gives about 80 percent kill of the roots also (23). It has given good control of bushhoneysuckle, wild cherries, juneberry, and poison ivy (see tables A and B in appendix). Relatively large amounts are needed for satisfactory results. It has proven effective when used as a foliage spray on growth up to 20 feet high and when applied in cups or frills cut into larger tree stems. As a foliage spray, it sometimes is more effective

than the hormone herbicides, but at a higher cost. The less frequent resprays needed, however, may offset the cost difference. Time of application during the growing season seems to affect results but little for hardwoods, but mid-summer applications were most effective on ponderosa pine (23, 19). However, one study indicated the poison to be much more effective when applied early in the morning than in the afternoon or evening (31). With a few exceptions (such as hazel), most woody plants sprout quite vigorously after having been killed back by ammonium sulfamate early in the growing season (13). Some harmful effects have attended the use of ammate. In two instances, 35-foot tall white pine died after poisonivy beneath it had been sprayed with ammonium sulfamate (36). In two others, 5-foot red pine succumbed after aspen over-topping them had been treated with ammate crystals in cups. It has been found that ammonium sulfamate, sodium arsenite, and sodium chlorate can be translocated from one red oak to another through natural root grafts, although 2,4,5-T apparently is not (28).

2,4,-D (2,4-dichlorophenoxyacetic acid) is similar to a plant growth hormone. It acts as a growth stimulant and presumably causes death by bringing about the exhaustion of food materials. It is readily absorbed by any healthy active plant part. It is absorbed more rapidly at higher than at lower temperatures. The addition of wetting agents or fructose have increased its toxicity. It is available in three general types of preparations: (1) Sodium or ammonium salts (dry powders which dissolve readily in water), (2) amine salts (liquid readily dissolved in water), and (3) esters (liquids which give milky color when added to water). In general, the salts and amines are slower in action than the esters. The quicker acting esters seem to have given better results with woody plants. 2,4-D is quite selective. It gives good control of such plants as alder, elder, black locust, sumac, and willows, but is rather ineffective on such plants as oaks, hickories, ashes, red maple, and most conifers (tables A and B).

2,4,5-T (2,4,5-trichlorophenoxyacetic acid) is also a "hormone" herbicide. In some species it is translocated more rapidly than 2,4-D, the rate being greatest at full leaf stage. High temperatures and low humidities favor translocation. It is available in formulations similar to those for 2,4-D (sodium salts, amine salts, and esters). Its action in the plant is similar to that of 2,4-D, but it is less selective than 2,4-D and is useful for eliminating certain plants which resist 2,4-D, such as aspen, wild cherries and plums, juneberry, brambles, poisonivy, and ribes (tables A and B). It has been found to inhibit root bud development much better than 2,4-D in certain plants. In general, 2,4,5-T is less soluble in common solvents than corresponding 2,4-D compounds. Frequently 2,4,5-T is used in mixture with 2,4-D as a brush killer. The older mixtures were largely made of equal proportions of the two substances; more recently they have also been made up of 1/3 2,4,5-T and 2/3 of the cheaper 2,4-D. Such mixtures have been effective on a large number of woody plants (tables A and B). Generally speaking, the ashes, maples, oaks, roses, redcedar, basswood, and beech have been resistant to hormone sprays (14, 32).

Indirect Effects of these Herbicides.- The hormone sprays and ammonium sulfamate are not directly poisonous to men or animals, but they do have some indirect effects. For example, some people are allergic to the hormone herbicides, and wearing gloves soaked in ammonium sulfamate solution may cause skin irritation. Sometimes livestock is poisoned indirectly by eating plants -- which in themselves are poisonous -- after they have been sprayed. It has been found that the sugar content of some plants increases 1 to 3 days after being sprayed with hormones. Animals seek out such plants even though they may be of species normally avoided. Wilted chokecherry foliage contains prussic acid and is poisonous to animals; they may consume it after spraying. Sometimes, too, there is an increase in nitrates in plant foliage after treatment with sublethal doses of 2,4-D. This also may be poisonous to some animals. Spraying in pastured areas should therefore be done with caution. Whether or not wildlife species are affected in the same manner as domestic livestock is not yet known, but possible harm from foliage sprays should be recognized.

Other Herbicides in Use

In addition to ammonium sulfamate and the phenoxyacetic acids, the following herbicides also have been in recent use in the Lake States:

Dinitro weed killers are complicated organic compounds used as yellow dyes. In weak solutions they are selective, but in strong solution they are non-selective herbicides. The dinitros are poisonous and inflammable under some conditions, but can be used without danger if reasonable care is exercised. They impart an indelible yellow stain to clothing and skin (24). Dinitro ortho secondary butyl phenol has been fairly effective as a stem spray in killing alder, aspen, and hawthorn (tables A and B). It kills leaves and stems rapidly when applied as a foliage spray, but vigorous sprouting follows (12).

TCA (sodium trichloroacetate) is a highly water-absorbent salt. It has been found most effective upon grasses but injures many trees and shrubs. It kills largely as a soil poison. The soil remains toxic for a few weeks, and under certain soil and weather conditions, for a year or longer (24). For example, red pine seedlings spring-planted in an area treated with 75 to 100 pounds per acre of TCA the previous fall suffered considerable leaf burning. In another test, red pine transplants were uninjured. Seedlings also were uninjured when planted at least three months after treating the soil with 50 pounds or less of TCA per acre but suffered severely when transplanted into soil treated six weeks previously with 25 pounds of TCA per acre (28).

Applying the Herbicides

The "hormone" herbicides and ammonium sulfamate may be applied as sprays to the foliage or the base of stems, in frills or girdles cut in the bark of trees, and to freshly cut stumps. Ammonium sulfamate may also be applied in the form of crystals to freshly cut stump tops and trunk girdles or cups. Depending upon the purposes for which they are used, the herbicides may be applied at several seasons, in various formulations, at a number of rates and concentrations, and by a wide variety of equipment.

Kinds of Application

Foliage sprays have been the most common method of applying the newer chemical herbicides. Such sprays have been used on plants up to 30 feet tall but are usually most effective on brush which is not over 6 feet tall and not extremely dense. It is important to use enough spray to wet the leaves and stems thoroughly. This usually requires from 100 to 300 gallons per acre of spray (14, 29). The hormone sprays are most commonly applied at the full leaf stage at concentrations of 1,000 to 4,000 p.p.m. (parts per million); ammonium sulfamate at about 1 pound per gallon of water.

Salts and amine forms of 2,4-D may be used in water sprays or in oil-water emulsions by the addition of an emulsifying agent. Esters are soluble in oil and form emulsions when dispersed in water (37). Kerosene and diesel oil commonly are used as diluents or for ester formulations of 2,4-D and 2,4,5-T.

Cut surface sprays also have been widely used. They usually are more effective than foliage sprays when brush is over six feet tall or very dense. Cut stump sprays have proved effective on several species resistant to foliage sprays. They have an advantage, in that they can be applied at any season. Stumps should be cut high enough to be easily found at the time of treatment, and it has proved helpful to add color (such as ordinary red cake dye) to the spray so that it is easy to tell which stumps have been treated and thus prevent misses. On the other hand, where it is likely that mowers will be used, the stumps should be cut as low as practicable. The tops and sides of the stumps should be thoroughly wetted with the sprays (14), which should be applied immediately after cutting. Cut surface sprays must be more concentrated than foliage sprays. About 10,000 to 50,000 p.p.m. of the hormone sprays in kerosene or diesel oil or 2 pounds to 9 pounds of ammonium sulfamate per gallon of water or oil ordinarily are used.

Basal sprays have recently been tested over a wide area with promising results. Although they may be used at any season, they have shown greatest promise when applied to dormant plants. Concentrated oil solutions or emulsions of the hormone herbicides are sprayed over the lower 1 to 2 feet of stem (17, 18). The spray should be applied heavily enough so that it completely encircles and runs down the stem. Concentrations of 10,000 to 60,000 p.p.m. of the hormone sprays in kerosene, diesel oil, or in emulsions usually are effective. Combinations of 2,4,5-T and ammonium sulfamate in oil solutions indicate promise. Recommendations are to use 4 to 20 gallons of spray per 1,000 sprout units (all sprouts arising from a single stem). Brush killer (combination of 2,4-D and 2,4,5-T) or 2,4,5-T ordinarily are much more effective than 2,4-D. Basal spraying has been recommended for use where the number of woody plants per acre does not exceed 1,000 (3). If there is appreciable resprouting, a follow-up foliage spray the next summer may be required.

Axe cuts, frills, or notches, into which herbicides are introduced, often are made near the base of larger trees. Ammonium sulfamate has been more successfully used in this manner than have the hormone sprays. Recommendations from the South are to place 1 tablespoon or 1/2 ounce of Ammonium sulfamate

crystals in 6-inch cups or notches made at the base of blackjack oak trees under 12 inches in d.b.h. For trees above this size, put ammonium sulfamate solution (2 to 4 pounds per gallon of water) in frills chopped around the tree 24 to 30 inches above ground (6, 7). Girdling, of course, is of some effect even without the use of poisons.

Season of Application

Season of application is of importance, especially for foliage sprays. Best results usually occur when spraying is done after the leaves are fully expanded and are synthesizing food which is being transported to the roots (9). Spraying of cut surfaces can be done effectively at most any season so long as it is carried out immediately after cutting. Poisoning through cuts, frills, or notches usually is done during the growing season. Dormant basal sprays appear to be most effective on some species if done early in the dormant season, and on others, if done late in the dormant season. This matter has not yet been well-worked out. With present knowledge, it has become possible to develop year-round spray schedules (4).

Concentrations and Rates

Rates of application of the "hormone" sprays usually are expressed in terms of the amount of acid equivalent - commonly stated on containers as pounds per gallon. In individual plant treatment, usually only the concentration in percent or parts per million (p.p.m.) is given.4/ Table 1 can be used as a guide for preparing spray solutions having any desired percentage or p.p.m. (37). As a rule of thumb, 1-1/4 ounces or 2-1/2 tablespoons of 40 percent acid equivalent material in one gallon of water will give a solution of 4,000 p.p.m.

Table 1.- Fluid measure of phenoxyacetic acid herbicide for spray solution containing 1,000 p.p.m. (0.1 percent) (37)

Acid equivalent of herbicide	Amount of spray solution when fluid measure of herbicide is -					
	1 ounce	4 ounces	½ pint	1 pint	1 quart	1 gallon
Pounds per gallon	Gallons					
2.00	1.88	7.5	15	30	60	240
3.00	2.80	11.2	22	45	90	360
3.34	3.12	12.5	25	50	100	400
4.00	3.75	15.0	30	60	120	480

4/ In this paper, concentrations frequently are given in p.p.m. because that is the way they were reported. But the same amount of herbicide will give solutions differing considerably in p.p.m., depending upon whether or not oils of various types or water are used as diluents or carriers. Since it is the actual amount of chemical applied that is important, it is considered preferable to report concentrations as pounds of active ingredients per unit volume of solution rather than as p.p.m. or percentages which are based on weight.

For area treatment, application rates usually are expressed in pounds of acid per acre. The actual sprayer output of spray material per acre must, of course, be known. A guide to the amount of herbicide required for application of specific amounts of acid per acre is provided by table 2 (37).

Table 2.- Amount of herbicide required for application of specific amounts of acid per acre (37)

Acid equivalent of herbicide	Amount of herbicide required in spray solution when rate of application per acre is -				
	1/2 pound	2/3 pound	3/4 pound	1 pound	1½ pound
Pounds per gallon			Pints		
2.00	2.00	2.67	3.00	4.00	6.00
3.00	1.33	1.78	2.00	2.67	4.00
3.34	1.20	1.60	1.80	2.40	3.60
4.00	1.00	1.33	1.50	2.00	3.00

Equipment Needed

Sprays may be applied with a variety of equipment ranging from small household spray guns to elaborate power sprayers and airplanes. For spot spraying and control of small patches, 3-gallon knapsack sprayers are quite satisfactory, as is also the back-pack "Hi-Fog" gun (a high-pressure type of mist sprayer) (30). For right-of-way spraying, a tractor mounted and operated sprayer with booms has been widely used. These are "low-volume" sprayers, usually applying 5 to 10 gallons per acre and operated at pressures of 30 to 100 pounds per square inch. Higher pressures are inadvisable in agricultural areas because of the danger to nearby vegetation from spray drift. However, where spray drift is not a factor, pressures of 200 or more pounds per square inch have been recommended as being more efficient. Pressures which are too low result in poor coverage of leaves and excessive run-off. For high-pressure spraying power turbine blowers have worked well using 30 to 40 gallons of spray per acre. Tractor and jeep-drawn power spray equipment has also been used commonly. Special spray cars mounted by batteries of six spray guns, somewhat like antiaircraft guns, have been used on railroad right-of-ways. For covering large areas of brush where danger of drift is negligible, airplane application appears to be the most feasible method (37). The planes usually apply from 2 quarts to 5 gallons of spray per acre. In Idaho, 2,4,5-T was applied to a brush-covered ponderosa pine plantation from a helicopter with promising results (15).

Herbicide spray equipment should be cleaned thoroughly before it is used for other purposes on susceptible plants. Strong ammonia solutions have been recommended for cleaning equipment used with the "hormone" sprays. Ammate corrodes metal and will damage equipment if not cleaned thoroughly soon after use.

Recently spray wands have been used to facilitate even application of basal sprays (3).

Frills, girdles, and cups usually are made with axes. The Cornell Tree Killing Tool has also been found useful for applying solutions of ammate and the "hormone" sprays.

The kinds of nozzles used on spray equipment are very important. For low-volume spraying with a knapsack sprayer, No. 59 or A90 "Monarch" nozzles or equivalent, or atomizing nozzles have been recommended (32). Some prefer fog nozzles or "pecan" nozzles on high-pressure sprayers (32). For basal stem sprays the "Hi-Fog gun" with No. 3 or No. 4 nozzles or knapsack sprayers with standard weed nozzles such as Spraying Systems No. 8004 or 6504 have given good results (30, 1). For stump treatment with knapsack sprayers, the full-jet No. 1 nozzle is good (1). In airplane spraying, nozzles with 1/4-inch openings have been used to cut down spray drift.

New Formulations of the Phenoxyacetic Acids

The ester formulations of 2,4-D and 2,4,5-T sold commercially for several years have generally been the lower alkyl esters, such as isopropyl, butyl, ethyl, and methyl esters. Recently new less-volatile esters have been produced. Commercially available now is the propylene glycol butyl ether ester of 2,4-D and also of 2,4,5-T. Also tested slightly are the pentasyl ester, the polyethylene glycol half ester, and the butoxy ethanol ester. Some of these new esters appear to be more effective in controlling certain woody plants than were the older more volatile esters (2). There have been indications that some of the new esters of 2,4-D are as effective on some formerly resistant species as the older esters of 2,4,5-T.

Cost of Chemical Brush Control

The cost of chemical control of woody plants depends on such factors as the kinds of chemicals used; the rate and concentrations used; the method of application; the kind, size, and density of vegetation treated; season; and prevailing wage rates. These may vary somewhat with each operation. In some instances, the dosage required for effective treatment may be so high as to make it uneconomical.

Some costs which have been reported are: $6.00 to $7.00 per acre to eliminate hazel brush averaging 20,000 stems per acre (38), $2.40 per acre to kill low value hardwoods (7), $13.00 to $44.00 (average $30.00) per acre for spraying power line right-of-ways (32) and $6.00 to $9.00 per acre for foliage sprays (16). Studies in the South have shown that the relative costs of several methods, using frilling as a basis, were as follows: frilling, 1.0; 2-hack girdle, 1.7-2.4; ammate in frills at 30-inch height, 1.8-2.0 (2 pounds per gallon) or 2.1-2.3 (4 pounds per gallon); ammonium sulfamate crystals in cups,

2.0-2.6 (at 30-inch height), or 2.1-3.0 (near ground) (6). Another report is that the annual maintenance cost of chemically controlled right-of-ways is one-third to one-half of that for comparable mechanical clearance (3). Scrub oaks were treated with ammonium sulfamate in frills at a cost of $2.49 per 100 trees (28).

Generally speaking, the esters of the "hormone" herbicides cost more than the salts; 2,4,5-T compounds cost more than comparable 2,4-D compounds, and ammonium sulfamate costs more than either because it must be applied in much higher concentrations than the "hormone" herbicides. Strictly on an area basis, hand spraying costs more than power spraying, and the latter costs more than airplane spraying. Yet each of these herbicides and methods has a place where it is better suited than others. Accordingly, no generally applicable statements on cost can be made. Various organizations with experience in control of brush along right-of-ways reported the cost of cutting brush to be from 1 to 5 times that of chemical sprays (32). Some estimates show much greater savings. Not considered in the cost is the more effective control generally provided by chemical herbicides.

Methods Suggested for the Lake States

Chemical control of woody plants has shown much promise, but complete kills with one treatment are seldom attained. In some cases, resprouting is sparse and weak enough so that no more treatments are needed. Often, however, follow-up sprays will be needed (20). In any event, results should not be evaluated until at least one full growing season after treatment.

According to present knowledge and indications, the most useful chemical methods for control of woody plants in the Lake States appear to be as follows:

1. On roadsides, right-of-ways, and firelines where complete brush kill along narrow strips is desired, use a mixture of 2,4-D, and 2,4,5-T in ester form (brush killer) or ammonium sulfamate applied when the plants are in full leaf. Where brush is continuous, use power sprayers equipped with booms. If only occasional clumps of brush need be removed, knapsack sprayers or the "Hi-Fog gun" may be most efficient. In such cases, dormant season basal sprays may prove best. Where growth must be cut, one man with a knapsack sprayer can keep up with a cutting crew and treat the stumps. The addition of a dye to the spray will help prevent missing stumps in the treatment. After the initial spraying, additional treatments may be needed at 2- to 4-year intervals to keep brush out. The following program has been suggested for complete brush control along right-of-ways. An initial spray, a lighter respray the second year, probably a light respray the third year, and touch-up sprays every 4 to 5 years thereafter. Solutions of 1 to 4 pounds of amate per gallon of diluent or 3,000 p.p.m. of brush killer applied in about 100 gallons of diluent per acre should be sufficient for foliage sprays. Heavier rates will be needed for cut-surface or basal sprays.

2. To release large coniferous plantations overtopped by broadleaf shrubs or low trees, use ester formulations of 2,4-D, 2,4,5-T or combinations of the two (depending upon the species to be killed) at concentrations of about 3,000 p.p.m. applied at the rate of about 2 to 3 gallons per acre by airplane or helicopter when the plants are in full leaf. Use of the helicopter in Idaho has been promising. A flying height of 75 to 100 feet was used rather than lower heights to avoid driving the spray through the overstory and onto the conifers (15). Fairly satisfactory kills of willows and alders overtopping pine have been obtained by airplane spraying in western Oregon.5/ Smaller areas could be covered in some instances by jeep- or tractor-drawn power sprayers or by knapsack or back-pack sprayers.

3. To prepare brushy areas for planting, airplane or helicopter application of the phenoxyacetic acid ester formulations in solutions containing 3,000 p.p.m. would seem best for large areas. Lower level flying could be used because there would be no damage from spray driven through the canopy. After the brush dies it may be desirable to burn off the area before planting (15). Ground preparation should be delayed until the following year (38).

4. To remove brush under mature pine prior to a regeneration cut, use mixtures of 2,4-D and 2,4,5-T or ammonium sulfamate applied by knapsack or back-pack sprayers if the brush is in scattered clumps or jeep- or tractor-mounted power sprayers if it is quite continuous.

5. To remove individual stems of nonmerchantable or undesirable trees, use ammonium sulfamate applied as sprays or crystals in stem "frills," cut cups, or on stumps. Frills should be cut completely around the stem. Use ammonium sulfamate at the rate of 1/2 ounce of crystals per cup or in solutions of 2 to 4 pounds per gallon of diluent. Ester formulations of 2,4-D, 2,4,5-T, or mixtures of the two can also be applied to cut stumps or sprayed around the base of trees in the dormant season. The basal sprays should wet the stem thoroughly on all sides for 1 to 2 feet above ground. They may be applied with a knapsack or back-pack sprayer, and ordinarily should contain 20,000 to 40,000 p.p.m. of the phenoxyacetic acids. Some workers, however, have obtained good results with concentrations of 8,000 to 10,000 p.p.m. at a saving in cost.

6. To thin dense clumps of young jack pine seems possible according to experience in Canada with lodgepole pine. There 2,4-D applied in early summer as a heavy mist, at the rate of 1/5 to 1 gallon per 200 gallons diesel oil per acre caused almost complete kills of young lodgepole pines 3 to 4 feet tall in stagnating stands (10). Similar treatments seem worthy of trial in overdense young jack pine stands. Basal sprays would permit more selection of trees.

5/ Letter of May 9, 1950, from Prof. V. H. Freed to Director E. L. Demmon.

More Research Needed

Chemical control of woody plants has become an accepted practice. However, the field is relatively new and new compounds are being produced so frequently that continued research, both basic and applied, is needed.

Basic studies of the movement of herbicides in plants should be made. Qualitative results can be obtained by using radioactive isotopes as tracers and recording their movements by radioautograph techniques. Quantitative results would require counting analyses through the use of Geiger-Müller or other suitable counters (5). The effect of penetrants (pentachlorophenol, turpentine, etc.) on the toxicity of hormone sprays should be worked out (28).

Continued studies are needed of new formulations as they are issued to determine their effectiveness on a wide variety of plants under different conditions of application. Experimentation with nozzles and spray equipment to develop better and more economical methods are needed. The influence of droplet size on effectiveness of various sprays should be determined.

The effectiveness of basal sprays applied at various times during the dormant season needs to be determined for many species. The influence of season of application for cut-surface sprays also needs clarification.

Studies should be made of the effect on intermingled conifers of ammonium sulfamate applied to broadleaf plants in the same stand.

There is also need for better understanding of the brush or weed species themselves, their ecological life history, their regeneration habits, and other important characteristics.

Materials and methods which are more effective, cheaper, safer, and simpler to apply than any previously known must be the goal of active research. Special effort should be made to find a chemical herbicide which will give a complete kill with one treatment.

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APPENDIX

Table A°- Lake States woody plants that can be controlled at different stages by various chemical herbicides (21, 25, 26, 27, 28, 33, 35, 36, 38)

Species name		Herbicide	Concentration or rate 1/	Kind of application 2/	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Alder, speckled	Alnus incana	2,4-D esters	6/ 1100-3300	FS	YS,E	M,MH,L
		2,4,5-T esters	1000-2000	FS	YS	E,M,MH
		2,4,5-T esters	4000-5000	BS	M	D
		7/ Comb. esters	8000	FS	M,MH	
		" "	8000	CS	MH	
		Ammate	50-200 lbs/A	FS		M,MH
		"	3/4-1 lbs/gal	FS		M
		"	20 lbs/A	CS		MH
		"	4 lbs/gal	CS		M
		8/ DNOSP	.05 lb/gal (oil)	FS,BS		M
Alder, green	Alnus crispa	2,4-D esters	2400	FS		M
		2,4,5-T esters	2400	FS		M
Apple, American crab	Malus coronaria	2,4-D esters	3000	FS	YS	E,M,MH
		Comb. esters	3000	FS	YS,E,M, MH	L
Apple prairie crab	Malus ioensis	Comb. esters	2 lbs/A	CS	D	

° Based on reports from several sources, some of which were conflicting.

1/ Diluent assumed to be water (about 100 gallons per acre) unless otherwise stated.

2/ FS, foliage spray; CS, cut surface; AX, frills, girdles, or gashes; BS, basal spray.

3/ YS, young seedlings; E, early season; M, mid-season -- growth succulent; MH, mid-season -- growth not succulent; L, late season; D, dormant.

4/ Complete top kill by one application. Satisfactory root kill often requires additional treatments.

5/ Killed by repeated application.

6/ Unless otherwise noted, concentrations are in parts per million (ppm).

7/ Combination of 2,4-D and 2,4,5-T, usually half and half.

8/ DNOSP, dinitro ortho secondary butyl phenol.

Species name		Herbicide	Concentration or rate 1/	Kind of application 2/	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Ash, green	Fraxinus pennsylvanica lanceolata	Comb. esters	4000-6000	FS	E,M	MH
		Ammate	3/4 lb/gal	FS	M	
Ash, white	Fraxinus americana	2,4,5-T esters	11 lbs/A (90 gal. water, 10-oil)	BS	D	
		Comb. esters	11 lbs/A (oil)	BS		D
Aspen, bigtooth	Populus grandidentata	Ammate	3/4-1 lb/gal.	FS		M
		DNOSP	.05 lb/gal.(kero.)	BS	M	
Aspen, quaking	Populus tremuloides	Comb. esters	3000	FS	YS,E,M	MH,L
		Comb. esters	11 lbs/A (oil)	BS	D	
		2,4,5-T esters	1000-2000	FS	M	
		2,4,5-T esters	8000 (diesel oil)	BS	M	
		2,4-D esters	1100-3300	FS		YS,E,M,MH
		2,4-D esters	8000 (diesel oil)	BS		M
		Ammate	50-200 lbs/A	FS		M,MH
		"	3/4-1 lb/gal.	FS,AX	YS	M
		DNOSP	.05 lb/gal (oil)	BS	M	
Bearberry	Arctostaphylos uva-ursi	2,4-D esters	3000	FS	M	
		Comb. esters	3000	FS	M	
Beech, American	Fagus grandifolia	2,4,5-T esters	10,000 (oil)	BS		D
Birch, paper	Betula papyrifera	2,4-D esters	2000-3000	FS		E,M,MH,L
		2,4,5-T esters	1000-2000	FS		E,M,MH
Blackberry	Rubus sp.	2,4,5-T esters	2000	FS	Y,E,M,MH,L	
		2,4,5-T esters	8000 (in oil)	BS	D	
		Comb. esters	1000-6000	FS	YS,E,M,MH	
		Ammate	3/4 lb/gal.	FS	M	

Species name		Herbicide	Concentration or rate 1/	Kind of application 2/	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Blueberry, lowbush	Vaccinium angustifolium	2,4-D esters	2000	FS		E,MH
		Ammate	2-4 lbs/gal.	FS	M,MH	
Blueberry, smoothleaf	Vaccinium angustifolium var. laevi-folium	2,4-D esters	38,400	FS		M
		2,4,5-T esters	19,200	FS		M
		Comb. esters	9,600	FS		M
Boxelder	Acer negundo	2,4-D esters	3000	FS		YS,E,M,MH
		Comb. esters	2000-3000	FS		YS,E,M,MH,L
		Comb. esters	2 lbs/A (oil)	CS	E	
Bracken	Pteridium aquilinum	Ammate	2-4 lbs/gal.	FS	M,MH	
Butternut	Juglans cinerea	2,4-D esters	3000	FS	YS	E,M
		Comb. esters	3000	FS	YS	E,M,MH,L
Bushhoney-suckle, dwarf	Diervilla lonicera	2,4-D esters	2400	FS		M
		2,4,5-T esters	2400	FS		M
		Comb. esters	2400	FS		M
		Ammate	1 lb/gal.	FS	MH	
Cherry, black	Prunus serotina	2,4-D esters	3000	FS	YS,E,M,MH	L
		2,4,5-T esters	1500-2000	FS	YS,E,M,MH	L
		Comb. esters	3000	FS	YS,E,M,MH,L	
		Comb. esters	2 lbs/A (oil)	CS	E	
		Ammate	1 lb/gal.	FS	YS,M	
Cherry, choke	Prunus virginiana	2,4-D esters	2000	FS		YS,E,M,MH
		2,4-D esters	4000 (oil)	BS		D
		2,4,5-T esters	4000	FS	M,MH	
		Comb. esters	3000	FS	YS,E,M,MH,L	
		Ammate	1 lb/gal.	FS	M	

Species name		Herbicide	Concentration or rate 1/	Kind of 2/ application	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Cherry, pin	Prunus pennsylvanica	2,4,5-T esters	1000-2000	FS	M,MH	
		2,4,5-T esters	5000 (oil)	BS	D	
		Comb. esters	3000	FS	YS,E,M,MH,L	
		Ammate	3/4-1 lb/gal.	FS	M,MH	
Chokeberry	Aronia sp.	Ammate	2-4 lbs/gal.	FS	M,MH	
Coralberry, Indian-currant	Symphoricarpos orbiculatus	2,4-D esters	2000	FS	YS,E,M,MH	
		Comb. esters	6000	FS	YS,E,M,MH	
Cottonwood, eastern	Populus deltoides	2,4-D esters	3000	FS	YS	E,M,MH,L
		Comb. esters	1000-3000	FS		E,M,MH
		Comb. esters	4000	FS	YS,M,MH	
		Ammate	2 lbs/stump	CS	E	
Cranberry, small	Vaccinium oxycoccus	2,4-D esters	9600	FS		M
		2,4,5-T esters	9600	FS		M
		Comb. esters	4800	FS		M
Creeper, Virginia	Parthenocissus quinquefolia	2,4-D esters	1000-2000	FS		YS,E,M
		2,4-D esters	1000-2000	CS	D	
		Comb. esters	3000	FS		YS,E,M,MH,L
American currant, black	Ribes americanum	2,4-D salts and esters	1000	FS	YS,E,M,MH,L	
		2,4,5-T esters	1000	FS	YS,E,M,MH,L	
		2,4,5-T esters	24,000	BS	E,M,MH,L	
		Comb. esters	1000	FS	YS,E,M,MH,L	
Currant swamp, black	Ribes lacustre	2,4,5-T esters	2000	FS,CS	YS,E,M,MH,L	
Currant swamp, red	Ribes triste	2,4,5-T esters	6000	FS		YS,E
		Comb. esters	6000	FS		YS,E

Species name		Herbicide	Concentration or rate 1/	Kind of 2/ application	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Dewberry, northern	Rubus flagellaris	Comb. esters	3000	FS		YS
Dogwood, red osier	Cornus stolonifera	2,4-D esters	1-2 lbs/A	FS		M
		Comb. esters	3000-6000	FS		E,M,MH
		2,4,5-T esters	4000	FS		M
Dogwood, roundleaf	Cornus rugosa	2,4-D esters	2400	FS		M
		2,4,5-T esters	2400	FS		M
		Comb. esters	2400	FS		M
Elder, American	Sambucus canadensis	2,4-D esters	3000	FS	YS,E,M,	MH,L
		2,4,5-T esters	2000	FS		M
		Comb. esters	1000-8000	FS	YS,E,M	L
		Ammate	3/4 lb/gal.	FS	M	
Elm, American	Ulmus americana	2,4-D esters	3000	FS	YS,E,M,MH	L
		2,4,5-T esters	1500	FS	YS,E,M	MH,L
		Comb. esters	3000+	FS	YS,E,M,MH	L
		Ammate	3/4 lb/gal.	FS	M	
Elm, slippery	Ulmus fulva	Comb. esters	4000-6000	FS	E,M,MH	
Elm, Siberian (Chinese)	Ulmus pumila	2,4-D salts and esters	1000	FS		YS
		2,4-D esters	96,000	CS		E,M
Filbert, (hazel) beaked	Corylus cornuta	2,4-D esters	2000	FS		E,M,MH
		2,4-D esters	4000	BS		D
		2,4,5-T esters	2000	FS		M,MH
		Comb. esters	1000-8000	FS		M,MH
		Ammate	50-200 lbs/A	FS		M,MH
		Ammate	3/4-1 lb/gal.	FS		M

Species name		Herbicide	Concentration or rate 1/	Kind of application 2/	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Filbert, (hazel) American	Corylus americana	2,4-D esters	1000-3300	FS		E,M,MH,L,D
		2,4,5-T esters	2000-3000	FS		M,MH
		2,4,5-T esters	8000 (in oil)	BS		D
		2,4,5-T esters	11 lbs/A (90-W 10-0)	BS	D	D
		Comb. esters	11 lbs/A (oil)	BS		D
Gooseberry, Missouri	Ribes missouriense	2,4,5-T esters	6000	FS	YS	E,M
		Comb. esters	6000	FS	YS	E,M
Gooseberry, prickly	Ribes cynosbati	2,4,5-T esters	6000	FS	YS	E,M
		2,4,5-T esters	24,000 (in oil)	BS	E,M	MH,L
		Comb. esters	6000	FS	YS	E,M
Gooseberry, smooth	Ribes hirtellum	2,4,5-T esters	6000	FS	YS	E,M
		Comb. esters	6000	FS	YS	E,M
Gooseberry, northern	Ribes oxyacanthoides	Comb. esters	2000-3000	FS		MH
		2,4-D esters and salts	2000	FS	M,MH	
Grape, riverbank	Vitis riparia	2,4-D esters	3000	FS	YS,E,M,MH,L	
		2,4-D esters	1000	CS	D	
		Comb. esters	1000+	FS	YS,E,M,MH,L	
		2,4,5-T esters	2000	FS	L	
		2,4,5-T esters	96,000	CS	E	
		Ammate	1 lb/gal.	FS	M	
Greenbrier, common	Smilax rotundifolia	2,4,5-T esters	8000 (in oil)	BS	D	
		Comb. esters	6000	FS	E,M,MH	
Hackberry	Celtis occidentalis	2,4-D esters	200,000	CS	M,MH	
		2,4-D esters	2000	FS	YS	

Species name		Herbicide	Concentration or rate 1/	Kind of 2/ application	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Hawthorn	Crataegus spp	2,4-D esters	4000	FS		YS,E,M,MH
		2,4-D esters	4000 (in oil)	BS		D
		2,4-D esters	1-2 lbs/A	FS	YS	E
		2,4,5-T esters	1500-4000	FS		YS,E,M
		Comb. esters	4000-6000	FS	E,M,MH	
		Comb. esters	8000 (in oil)	CS	MH	
		Ammate	3/4-1 lb/gal.	FS		M
		DNOSP	.05 lb/gal. (oil)	BS		M
Hickory, shellbark	Carya ovata	2,4-D esters	3000	FS		YS
		2,4,5-T esters	8000 (in oil)	BS	D	
		Comb. esters	3000	FS	YS	E,M,MH
		Ammate	3/4 lb/gal.	FS	M	
Hickory, bitternut	Carya cordiformis	Comb. esters	11 lbs/A (oil)	BS	M	
Honeysuckle, hairy	Lonicera hirsuta	2,4-D esters	2400	FS		M
Hophornbeam, American (Ironwood)	Ostrya virginiana	2,4,5-T esters	10,000 (oil)	BS	D	
Juneberry	Amelanchier alnifolia	2,4-D esters	1100-3300	FS		M,MH,L
		2,4-D esters and salts	1-4 lbs/A	FS		E,M
		Comb. esters	2000	FS	MH	
		2,4,5-T esters	3000	FS	YS,E,M,MH,L	
		Ammate	50-200 lbs/A	FS		M,MH
		Ammate	3/4-1 lb/gal.	FS	YS,M	
Labradortea	Ledum groenlandicum	2,4-D esters	38,400	FS		MH
		2,4,5-T esters	38,400	FS		MH
		Comb. esters	19,200-38,400	FS		MH

Species name		Herbicide	Concentration or rate 1/	Kind of application 2/	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Laurel, swamp	Kalmia polifolia	2,4-D esters	38,400	FS		MH
		2,4,5-T esters	38,400	FS		MH
		Comb. esters	38,400	FS		MH
Leatherleaf	Chamaedaphne calyculata	2,4-D esters	38,400	FS		MH
		2,4,5-T esters	19,200	FS		MH
		Comb. esters	19,200	FS		MH
Lingonberry	Vaccinium vitis-idaea minus	2,4-D esters	9600	FS		MH
		Comb. esters	19,200	FS		MH
Locust, black	Robinia pseudoacacia	2,4-D esters	3000	FS	YS,E,M	MH,L
		2,4-D esters and amines	2 lbs/A	FS		M,MH
		2,4,5-T esters	1500	FS	YS,E,M	MH,L
		2,4,5-T esters	2000	AX	L	
		Comb. esters	3000-6000	FS	E,M,MH	
Maple, red	Acer rubrum	2,4,5-T esters	2000	FS		M
		2,4,5-T esters	8000 (oil)	BS	M	
		Comb. esters	6000	FS	YS,E,M,MH	
		Comb. esters	8000 (in oil)	CS	MH	
		Ammate	3/4-1 lb/gal.	AX		M
		Ammate	2-4 lbs/gal.	FS	M,MH	
Maple, mountain	Acer spicatum	Comb. esters	8000 (in oil)	CS	MH	
Maple, silver	Acer saccharinum	Comb. esters	3000	FS	E,M,MH	
		2,4,5-T esters	1000	FS	L	
Maple, sugar	Acer saccharum	Comb. esters	3000	FS		YS,E,M
		2,4-D esters	8000 (in oil)	CS		D
		2,4,5-T esters	3000	FS		E,MH

Species name		Herbicide	Concentration or rate 1/	Kind of application 2/	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Maple, striped	Acer pennsylvanicum	Comb. esters	3000	FS		YS,E
Oak, bur	Quercus macrocarpa	2,4-D esters	1500	FS		M,MH
		2,4,5-T esters	1000-2000	FS		M
		Comb. esters	1½ lbs/A	FS		M,MH
Oak, mixed red and white	Quercus spp.	2,4-D esters	48 lbs/100 gals. (oil)	BS		D
		2,4,5-T esters	4-48 lbs/100 gals. (oil)	BS		D
Oak northern red	Quercus borealis	Comb. esters	6000	FS	YS,E,M,MH	
		Ammate	50-200 lbs/A	FS,CS		M,MH
Oak, northern pin	Quercus ellipsoidalis	Ammate	1 tbsp. per frill	AX		M
Oak, scarlet	Quercus coccinea	Comb. esters	4000-6000	FS	E,M,MH	
		Ammate	50-200 lbs/A	FS,CS		M,MH
Oak, white	Quercus alba	2,4,5-T	1500	FS	YS,E,M	MH,L
		Comb. esters	4000-6000	FS	E,M,MH	
		Ammate	50-200 lbs/A	FS,CS		M,MH
Pine, eastern white	Pinus strobus	2,4-D esters	6000+	FS	YS	
		Comb. esters	3000	FS		YS,E
		Ammate	1 lb/gal.	FS	YS	M
Pine, red	Pinus resinosa	Comb. esters	3000	FS		YS,E,M
		Ammate	80 lbs/A	FS	YS	MH,L
Poisonivy, common	Toxicodendron radicans	2,4-D esters	2000-3000	FS	YS	E,M,MH
		2,4,5-T esters	1000-2000	FS	YS,E,M,MH	L
		Comb. esters	1000-3000	FS	YS,E,M,MH	L
		Ammate	100,000	FS	E	

Species name		Herbicide	Concentration or rate 1/	Kind of application 2/	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Maple, striped	Acer pennsylvanicum	Comb. esters	3000	FS		YS,E
Oak, bur	Quercus macrocarpa	2,4-D esters	1500	FS		M,MH
		2,4,5-T esters	1000-2000	FS		M
		Comb. esters	1½ lbs/A	FS		M,MH
Oak, mixed red and white	Quercus spp.	2,4-D esters	48 lbs/100 gals. (oil)	BS		D
		2,4,5-T esters	4-48 lbs/100 gals. (oil)	BS		D
Oak northern red	Quercus borealis	Comb. esters	6000	FS	YS,E,M,MH	
		Ammate	50-200 lbs/A	FS,CS		M,MH
Oak, northern pin	Quercus ellipsoidalis	Ammate	1 tbsp. per frill	AX		M
Oak, scarlet	Quercus coccinea	Comb. esters	4000-6000	FS	E,M,MH	
		Ammate	50-200 lbs/A	FS,CS		M,MH
Oak, white	Quercus alba	2,4,5-T	1500	FS	YS,E,M	MH,L
		Comb. esters	4000-6000	FS	E,M,MH	
		Ammate	50-200 lbs/A	FS,CS		M,MH
Pine, eastern white	Pinus strobus	2,4-D esters	6000+	FS	YS	
		Comb. esters	3000	FS		YS,E
		Ammate	1 lb/gal.	FS	YS	M
Pine, red	Pinus resinosa	Comb. esters	3000	FS		YS,E,M
		Ammate	80 lbs/A	FS	YS	MH,L
Poisonivy, common	Toxicodendron radicans	2,4-D esters	2000-3000	FS	YS	E,M,MH
		2,4,5-T esters	1000-2000	FS	YS,E,M,MH	L
		Comb. esters	1000-3000	FS	YS,E,M,MH	L
		Ammate	100,000	FS	E	

Species name		Herbicide	Concentration or rate 1/	Kind of application 2/	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Plum, American	Prunus americana	2,4-D esters	2000	FS	E	M,MH
		Comb. esters	6000	FS	E,M,MH	
Plum, Canada	Prunus nigra	2,4,5-T esters	2000	FS	YS,E,M,MH	
Poplar, balsam	Populus balsamifera	Comb. esters	2000	FS	MH	
		2,4-D esters	1½ lbs/A	FS		YS,E
Pricklyash	Zanthoxylum americanum	2,4-D esters	2000-8000	FS		M,MH
		2,4-D esters	50,000-250,000 (turp.)	BS		D
		2,4,5-T esters	2000-8000	FS		M,MH
		2,4,5-T esters	25,000-50,000	BS		D
		Comb. esters	2000-8000	FS		M,MH
Raspberry, black	Rubus occidentalis	Comb. esters	3000	FS	YS,E,M,MH,L	
		Ammate	50-200 lbs/A	FS		M,MH
Redcedar, eastern	Juniperus virginiana	Comb. esters	6000	FS		YS,E,M,MH
Rose, wild	Rosa spp.	2,4,5-T esters	½-2 lbs/A	FS		M
		Comb. esters	2000	FS		MH
		Ammate	50-200 lbs/A	FS		M,MH
Sassafras	Sassafras albidum	2,4-D esters	3000	FS	YS,E,M,MH,L	
		Comb. esters	4000+	FS	E,M,MH	
		2,4,5-T esters	1500+	FS	YS,E,M,MH,L	
		Ammate	2-4 lbs/gal.	FS	M,MH	
Snowberry, western	Symphoricarpos occidentalis	2,4-D esters	1000-4000	FS		M,MH
		Comb. esters	2000-4000	FS		E,M,MH
Spirea, meadowsweet, narrowleaf	Spiraea alba	2,4-D acid	1000	FS		MH
		Comb. esters	1000	FS		MH
		2,4,5-T esters	4800	FS		MH

Species name		Herbicide	Concentration or rate 1/	Kind of 2/ application	Season 3/ at which obtained	
Common	Scientific				Good control 4/	Fair control 5/
Sumac, staghorn	Rhus typhina	2,4-D esters	3000	FS	YS,E,M,MH,L	
		2,4,5-T esters	15,000	FS	YS,E,M,MH,L	
		Comb. esters	3000	FS	YS,E,M,MH,L	
		Ammate	3/4 lb/gal.	FS	M,MH	
Sumac, smooth	Rhus glabra	Comb. esters	6000	FS	E,M,MH	
		2,4-D esters	2000	FS	YS,E,M,MH	
		2,4,5-T esters	1000-2000	FS	YS,E,M,MH,L	
		Ammate	3/4 lb/gal.	FS	M,MH	
Sweetfern	Comptonia peregrina	2,4-D esters	3000	FS	E,MH	
		Ammate	2-4 lbs/gal.	FS	M,MH	
Wahoo, eastern	Euonymus atropurpureus	2,4,5-T esters	2000	FS		L
Walnut, black	Juglans nigra	Comb. esters	3000	FS	YS	E,M,MH
Willows	Salix spp.	2,4-D esters	3000	FS	YS,E,M	MH,L,D
		2,4-D esters	3000	CS	YS,E	M,MH,L
		2,4,5-T esters	2000	FS	YS,E,M,MH	L
		Comb. esters	1000-4000	FS	YS,E,M,MH	L
		Ammate	50-200 lbs/gal.	FS		M,MH
		Ammate	3/4-1 lb/gal.	FS		M,MH
Witchhazel	Hamamelis virginiana	Comb. esters	3000	FS		M,MH

Table B.- Woody plants of the Lake States that can be controlled by spraying foliage with chemical herbicides 1/

Species killed by one application at some stage of growth 2/	Species killed only by repeated applications
2, 4-D	
Speckled alder, bearberry, black cherry, Indian-currant coralberry, Virginia creeper,° American black currant, American elder, American elm, sweetfern, northern gooseberry, riverbank grape, hackberry,° black locust, American plum, sassafras, smooth sumac, staghorn sumac, willows.	Green alder, quaking aspen, paper birch, blueberry, boxelder, bush-honeysuckle, butternut, chokecherry, eastern cottonwood, American crab-apple, small cranberry, redosier dogwood, roundleaf dogwood, Siberian elm, American filbert (hazel), beaked filbert (hazel), hawthorn, hairy honeysuckle, juneberry, labra-dortea, swamp laurel, leatherleaf, lingonberry, sugar maple,° bur oak, balsam poplar, common poisonivy, pricklyash, western snowberry, narrowleaf meadowsweet spirea.
2, 4, 5-T	
Quaking aspen, wild blackberry, black cherry, chokecherry, pin cherry, American black currant, swamp black currant, American elm, riverbank grape, juneberry, black locust, silver maple, white oak Canada plum, common poisonivy, sassafras, staghorn sumac, smooth sumac, willows.	Green alder, speckled alder, paper birch, smoothleaf blueberry, bush-honeysuckle, small cranberry, swamp red currant, roundleaf dogwood, red-osier dogwood, American elder, American filbert (hazel), beaked filbert (hazel), Missouri gooseberry, prickly goose-berry, smooth gooseberry, hawthorn, labradortea, swamp laurel, leatherleaf, red maple, sugar maple, bur oak, pricklyash, wild rose, narrowleaf meadowsweet spirea, eastern wahoo.

1/ See Table A for type of herbicide, method of application, season, and growth stage which are affective.

2/ Other than young seedling stage, which is easily killed in most species. This refers to top kill; to kill the roots of many species requires more than one application.

° Spraying on cut surfaces.

Table B (Continuod)

Species killed by one application at some stage of growth 2/	Species killed only by repeated applications
Combinations of 2,4-D and 2,4,5-T	
Speckled alder, green ash, quaking aspen, bearberry, wild blackberry, Indian-currant coralberry, black cherry, chokecherry, pin cherry, eastern cottonwood, American crab-apple, prairie crabapple,° American black currant, American elder, American elm, slippery elm, riverbank grape, common greenbrier, hawthorn, juneberry, black locust, red maple, mountain maple,° silver maple, common poisonivy, northern red oak, white oak, scarlet oak, American plum, balsam poplar, black raspberry, sassafras, staghorn sumac, smooth sumac, willows.	Smoothleaf blueberry, bushhoneysuckle, buttornut, small cranberry, Virginia creeper, boxelder, swamp red currant, northern dewberry, redosier dogwood, roundleaf dogwood, beaked filbert, Missouri gooseberry, prickly goose-berry, smooth gooseberry, northern gooseberry, shellbark hickory, labra-dortea, swamp laurel, leatherleaf, lingonberry, sugar maple, striped maple, bur oak, eastern white pine, red pine, pricklyash, eastern red-cedar, wild rose, western snowberry, narrowleaf meadowsweet spiraea, black walnut, witchhazel.
Ammate	
Green ash, wild blackberry, lowbush blueberry, bracken, dwarf bush-honeysuckle, black cherry, choke-berry, chokecherry, pin cherry, cottonwood,° American elder, American elm, riverbank grape, shellbark hickory, juneberry, red maple, common poisonivy, sassafras, staghorn sumac, smooth sumac, sweetfern.	Speckled alder, bigtooth aspen, quaking aspen, beaked filbert, hawthorn, northern red oak, scarlet oak, white oak, eastern white pine, red pine, black raspberry, wild rose, willows.
DNOSP	
	Speckled alder.

Table B (Continued)

Species killed by one application at some stage of growth 2/	Species killed only by repeated applications
Combinations of 2,4-D and 2,4,5-T	
Speckled alder, green ash, quaking aspen, bearberry, wild blackberry, Indian-currant coralberry, black cherry, chokecherry, pin cherry, eastern cottonwood, American crabapple, prairie crabapple,° American black currant, American elder, American elm, slippery elm, riverbank grape, common greenbrier, hawthorn, juneberry, black locust, red maple, mountain maple,° silver maple, common poisonivy, northern red oak, white oak, scarlet oak, American plum, balsam poplar, black raspberry, sassafras, staghorn sumac, smooth sumac, willows.	Smoothleaf blueberry, bushhoneysuckle, buttternut, small cranberry, Virginia creeper, boxelder, swamp red currant, northern dewberry, redosier dogwood, roundleaf dogwood, beaked filbert, Missouri gooseberry, prickly gooseberry, smooth gooseberry, northern gooseberry, shellbark hickory, labradortea, swamp laurel, leatherleaf, lingonberry, sugar maple, striped maple, bur oak, eastern white pine, red pine, pricklyash, eastern redcedar, wild rose, western snowberry, narrowleaf meadowsweet spiraea, black walnut, witchhazel.
Ammate	
Green ash, wild blackberry, lowbush blueberry, bracken, dwarf bushhoneysuckle, black cherry, chokeberry, chokecherry, pin cherry, cottonwood,° American elder, American elm, riverbank grape, shellbark hickory, juneberry, red maple, common poisonivy, sassafras, staghorn sumac, smooth sumac, sweetfern.	Speckled alder, bigtooth aspen, quaking aspen, beaked filbert, hawthorn, northern red oak, scarlet oak, white oak, eastern white pine, red pine, black raspberry, wild rose, willows.
DNOSP	
Speckled alder.	

Table C.- Partial list of producers of herbicides 1/

Hormone (2,4-D, 2,4,5-T) Herbicides

American Chemical Paint Co.
Agricultural Chemicals Division
Ambler, Pennsylvania

Chemical Corporation of Colorado
Denver, Colorado

Chipman Chemical Company, Inc.
Chicago, Illinois

The Dow Chemical Company
Midland, Michigan

E. I. DuPont de Nemours & Co., Inc.
Grasselli Chemicals Department
Wilmington 98, Delaware

Geigy Company, Inc.
89 Barclay Street
New York 8, New York

Monsanto Chemical Company
1700 South Second Street
St. Louis 4, Missouri

Oldbury Electro Chemical Co.
Niagara Falls, New York

Pittsburgh Agricultural Chemical Co.
Empire State Building
350 Fifth Avenue
New York 1, New York

Ralston Purina Company
Sanitation - Farm Supply Dept.
St. Louis 2, Missouri

Standard Agricultural Chemicals, Inc.
13th & Jefferson Streets
Hoboken, New Jersey

Standard Oil Company
Chicago, Illinois

Thompson-Hayward Chemical Co.
Kansas City 8, Missouri

Trichloroacetate (TCA)

American Chemical Paint Co.
Agricultural Chemicals Division
Amber, Pennsylvania

The Dow Chemical Company
Midland, Michigan

E. I. DuPont de Nemours & Co., Inc.
Grasselli Chemicals Department
Wilmington 98, Delaware

Geigy Company, Inc.
89 Barclay Street
New York 8, New York

Oldbury Electro Chemical Co.
Niagara Falls, New York

Dinitro Weed Killers

Chipman Chemical Company, Inc.
Chicago, Illinois

The Dow Chemical Company
Midland, Michigan

E. I. DuPont de Nemours & Co., Inc.
Grasselli Chemicals Department
Wilmington 98, Delaware

Standard Agricultural Chemicals Co.
Hoboken, New Jersey

Ammonium Sulfamate

E. I. DuPont de Nemours & Co., Inc.
Grasselli Chemicals Department
Wilmington 98, Delaware

1/ This list is included for information only. It does not purport to be complete, and the listing herein implies neither discrimination against nor endorsement of dealers or their products.

Table D.- Partial list of manufacturers of spraying equipment 1/

John Bean Division
Food Machinery & Chemical Corp.
Lansing 4, Michigan

E and E Sprayer Company
Waverly, Nebraska

Original Enderes Company
Guttenberg, Iowa

The Engine Parts Mfg. Co.
1360 West 9th Street
Cleveland 13, Ohio

Hanson Chemical & Equipment Co.
Beloit, Wisconsin

The Hardie Manufacturing Co.
Hudson, Michigan

Kupfer Products, Inc.
Madison, Wisconsin

Monarch Manufacturing Works, Inc.
2501 East Ontario Street
Philadelphia 34, Pennsylvania

Spraying Systems Company
3201 Randolph Street
Bellwood, Illinois

Tryco Manufacturing Co., Inc.
Forsyth, Illinois

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